Injury pattern and mortality of noncompressible torso hemorrhage in UK combat casualties

Jonathan J. Morrison, MRCS, Adam Stannard, MRCS, Todd E. Rasmussen, MD, Jan O. Jansen, FRCS, FFICM, Nigel R.M. Tai, FRCS, *and* **Mark J. Midwinter, MD, FRCS,** *Birmingham, United Kingdom*

BACKGROUND: Hemorrhage following traumatic injury is a leading cause of military and civilian mortality. Noncompressible torso hemorrhage (NCTH) has been identified as particularly lethal, especially in the prehospital setting.

METHODS: All patients sustaining NCTH between August 2002 and July 2012 were identified from the UK Joint Theatre Trauma Registry. NCTH was defined as injury to a named torso axial vessel, pulmonary injury, solid-organ injury (Grade 4 or greater injury to the liver, kidney, or spleen) or pelvic fracture with ring disruption. Patients with ongoing hemorrhage were identified using either a systolic blood pressure of less than 90 mm Hg or the need for immediate surgical hemorrhage control. Data on injury pattern and location as well as cause of death were analyzed using univariate and multivariate analyses.

RESULTS: During 10 years, 296 patients were identified with NCTH, with a mortality of 85.5%. The majority of deaths occurred before hospital admission (n = 222, 75.0%). Of patients admitted to hospital, survivors (n = 43, 14.5%) had a higher median systolic blood pressure (108 [43] vs. 89 [46], $p = 0.123$) and Glasgow Coma Scale (GCS) (14 [12] vs. 3 [0], $p < 0.001$) compared with in-hospital deaths (n = 31, 10.5%). Hemorrhage was the more common cause of death (60.1%), followed by central nervous system disruption (30.8%), total body disruption (5.1%), and multiple-organ failure (4.0%). On multivariate analysis, major arterial and pulmonary hilar injury are most lethal with odds ratio (95% confidence interval) of 16.44 (5.50–49.11) and 9.61 (1.06–87.00), respectively.

CONCLUSION: This study demonstrates that the majority of patients sustaining NCTH die before hospital admission, with exsanguination and central nervous system disruption contributing to the bulk cause of death. Major arterial and pulmonary hilar injuries are independent predictors of mortality. (*J Trauma Acute Care Surg*. 2013;75: S263–S268. Copyright © 2013 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Epidemiologic study, level III.

KEY WORDS: Wartime injury; noncompressible torso hemorrhage; vascular trauma.

Hemorrhage is the leading cause of potentially preventable death on the battlefield, with the torso identified as the primary focus in 80% of cases.[1–4] Deaths from extremity hemorrhage now constitute a minority of deaths owing to the effective prehospital use of hemorrhage control adjuncts such as tourniquets.[5–7]

These observations have generated renewed interest in noncompressible torso hemorrhage (NCTH), which is the disruption of a named axial vessel or vessels within the pulmonary parenchyma of the chest, the solid organs of the abdomen, or those of the boney pelvis.[8] This definition has recently been applied to a US population of wartime injured who survived to medical treatment facility (MTF) admission (defined as a North Atlantic Treaty Organization Role III facility) and identified vascular and pulmonary injury as the most mortal injury complexes.[9] The in-hospital mortality rate of patients sustaining NCTH was 18.7%, which is considerably greater than the overall in-hospital mortality (or died of wounds [DOW] rates), of 4.8%, demonstrating the lethality of NCTH.[10]

Furthermore, a recent US Joint Trauma System study reviewed 4,596 US military deaths and identified that 9 of 10 battlefield deaths occurred before MTF admission.[4] With the use of previously established criteria to define catastrophic injury, 24.3% of the cohort was considered potentially survivable, of which hemorrhage constituted 90.9% of the deaths. The torso constituted the largest source of hemorrhage (67.3%), followed by junctional (19.2%) and extremity (13.5%).

It is unclear whether the injury pattern of patients with NCTH who die in the pre-MTF phase of care is different from patients surviving to MTF admission. This is important to understand to direct research strategies into the prehospital management of NCTH. The aim of this study was to examine a complete population of patients with NCTH, injured in wartime, to characterize the injury pattern before and after MTF admission.

PATIENTS AND METHODS

This study was conducted with the approval from the Royal Centre for Defence Medicine Academic Unit. The prospectively collected UK Joint Theatre Trauma Registry (JTTR) was used to

Submitted: January 15, 2013, Revised: January 29, 2013, Accepted: May 1, 2013.

From the Academic Department of Military Surgery and Trauma (J.J.M., A.S., N.R.M.T., M.J.M.), Royal Centre for Defence Medicine, Birmingham; Academic Unit of Surgery (J.J.M.), Glasgow Royal Infirmary, Glasgow; 16 Medical Regiment (J.O.J., N.R.M.T.), United Kingdom; US Army Institute of Surgical Research (J.J.M., T.E.R.), Fort Sam Houston; and 59th Medical Deployment Wing (T.E.R.), Science and Technology Section, Lackland Air Force Base, San Antonio, Texas; and The Norman M. Rich Department of Surgery (T.E.R.), the Uniformed Services University of the Health Sciences, Bethesda, Maryland.

The viewpoints expressed in this article are those of the authors and do not reflect the official position of the UK Defence Medical Service or the US Department of Defense.

Address for reprints: Jonathan J. Morrison, The Academic Department of Military Surgery and Trauma, Royal Centre for Defence Medicine, Birmingham, UK; email: jjmorrison@outlook.com.

DOI: 10.1097/TA.0b013e318299da0a

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **01 AUG 2013**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Injury pattern and mortality of noncompressible torso hemorrhage in UK combat casualties.**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Morrison J. J., Stannard A., Rasmussen T. E., Jansen J. O., Tai N. R. M, Midwinter M. J.,**	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **United States Institute of Surgical Research, JBSA Fort Sam Houston, TX**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

retrospectively identify all UK military personnel sustaining NCTH between August 2002 and July 2012 in Iraq or Afghanistan.

NCTH was defined using a previously published definition based on anatomic injury accompanied by physiologic or procedural indices of shock.[8] *Anatomic* refers to those injuries to a named torso vessel, pulmonary injury (massive hemothorax or hilar), Grade 4 or greater solid-organ injury (liver, kidney, or spleen), or pelvic fracture associated with ring disruption and hemorrhage. Named torso vessel was further subdivided into major/minor arteries/veins, depending on whether they were a direct branch/tributary of the aorta/inferior vena cava. *Physiologic* refers to a systolic blood pressure of less than 90 mm Hg, or *procedurally* refers to the need for an immediate laparotomy, thoracotomy, or pelvic fixation to control hemorrhage.

The UK JTTR is a performance improvement tool, which captures clinical data on casualties admitted to UK MTFs.[11] In the case of UK personnel, this includes data from the point of wounding through to discharge from a UK mainland hospital facility. Patients who died before reaching an MTF are classified as killed in action (KIA) and patients who survive to admission but ultimately succumb to their injuries are termed DOWs. Surviving patients are considered wounded in action (WIA). Postmortem data from patients who are KIA and DOW are also entered into the UK JTTR, permitting the comprehensive analysis of a population with wartime injuries. This system of classification enables the calculation of case fatality rates (CFRs), a metric of lethality, expressed as a percentage: CFR = [KIA + DOW] / [KIA + DOW + WIA].[12]

Information retrieved from the JTTR included patients demographic data, month of injury, injury pattern, outcome, as well as cause and location of death. The 2005 Military Abbreviated Injury Scale (AIS) scores[13] were used to calculate both the Injury Severity Score (ISS)[14] and the New Injury Severity Score (NISS).[15] In patients surviving to MTF admission, admission systolic blood pressure, heart rate, Glasgow Coma Scale (GCS) scores, and any operative intervention were also retrieved.

Statistical Analysis

Initially, the demography of the KIA, DOW, and WIA groups was compared using χ^2 tests for categorical data and analysis of variance for continuous data. In patients surviving to hospital, admission physiology and rates of operative intervention were compared. CFR data were then presented based on operational theater, temporal trend, and NCTH injury domains (named vessel, pulmonary, solid-organ injury, and pelvic injury). The injury pattern was compared between the following patient groups: patients surviving to admission (WIA + DOW) versus patients dying before admission (KIA) and survivors (WIA) versus nonsurvivors (KIA + DOW). Multivariate analysis was then used to control for multiple injuries to identify which injury patterns were most lethal.

RESULTS

During the 10-year study period, 296 patients were identified from the UK JTTR having sustained NCTH (Table 1). The majority of patients (n = 222, 75.0%) had died before MTF

TABLE 1. General Demographic Characteristics, Trauma Scores, Admission Physiology, and Operative Intervention of Patients With NCTH

	Survivors	Nonsurvivors		
	WIA	DOW	KIA	*p*
n	43	31	222	
Male, n (%)	43 (100%)	31 (100%)	218 (98.2%)	0.509
Age, median (interquartile range [IQR])	23 (8)	23 (8)	26 (9)	0.088
Theater of operations				
Iraq, n (%)	6 (10.3)	3 (5.2)	49 (84.5)	0.160
Afghanistan, n (%)	37 (15.5)	28 (11.8)	173 (72.7)	
Mechanism of injury				
Explosion, n (%)	27 (62.8)	21 (67.7)	155 (69.8)	0.789
Gunshot, n (%)	13 (30.2)	9 (29.0)	52 (23.4)	
Other, n (%)	3 (7.0)	1 (3.2)	15 (78.9)	
Trauma scores				
ISS, median (IQR)	26 (21)	57 (33)	75 (18)	< 0.001
NISS, median (IQR)	34 (28)	75 (18)	75 (0)	< 0.001
Physiology				
Systolic blood pressure	108 (43)	89 (46)	n/a	0.123
Heart rate	100 (52)	100 (128)	n/a	0.025
GCS score	14 (12)	3 (0)	n/a	0.001
Operative intervention				
Resuscitative thoracotomy, n (%)	4 (9.5)	14 (51.9)	n/a	< 0.001
Thoracotomy, n (%)	7 (16.7)	4 (14.8)	n/a	0.838
Laparotomy, n (%)	27 (64.3)	15 (55.6)	n/a	0.468
Pelvic external-fixation, n (%)	9 (21.4)	5 (18.5)	n/a	0.769

DOW, died of wounds; KIA, killed in action; n/a, not applicable; WIA, wounded in action.

admission and were classified as KIA. Of the 74 patients (25.0%) surviving to admission, there were 43 WIA and 31 DOW, generating an overall CFR for NCTH of 85.5%. The distribution of sex, age, theater of operations (Iraq vs. Afghanistan), and mechanism of injury among the WIA, DOW, and KIA groups were similar ($p > 0.05$). However, there was a significant increase in injury burden observed across the WIA, DOW, and KIA groups, respectively, as measured by both ISS and NISS ($p < 0.001$).

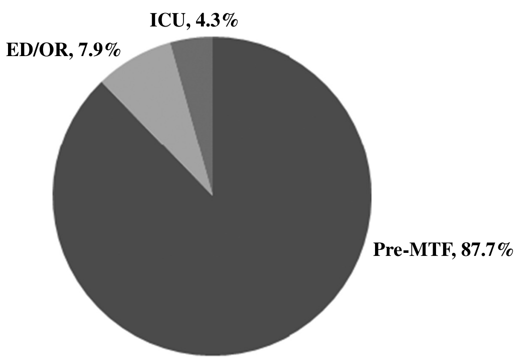
Of the patients admitted to hospital, those who survived presented with a higher median (interquartile range) systolic blood pressure (108 [43] vs. 89 [46], $p = 0.123$) and GCS score (14 [12] vs. 3 [0], $p < 0.001$) (Table 1). In terms of operative intervention, resuscitative thoracotomy was used significantly more in the DOW group (51.9% vs. 9.5%, $p < 0.001$), although thoracotomy, laparotomy, and pelvic fixation was used similarly between the WIA and DOW groups ($p > 0.1$)

When examining the location of the 253 deaths, the majority (87.7%) occurred in the pre-MTF setting, with 7.9% in the emergency/operating room and 4.3% in the intensive care unit (Fig. 1*A*). In terms of cause of death, while all patients had sustained NCTH, it was not the primary focus of injury in all patients. Torso hemorrhage accounted for 60.1% of deaths, but central nervous system (CNS) disruption (brain or spinal cord injury) accounted for 30.8%, total body destruction accounted for 5.1%, and multiorgan failure accounted for 4.0% (Fig. 1*B*).

TABLE 2. The CFR for the Overall Cohort, Operational Theater, Time, and NCTH Anatomic Domain

		CFR	*p*
	Overall	85.5%	
Operational theater			
	Iraq	89.7%	0.407
	Afghanistan	84.5%	
Period			
	August 2002 to May 2008	90.9%	0.155
	May 2008 to December 2011	83.8%	
	December 2011 to July 2012	81.6%	
NCTH domain			
	Vascular	93.0%	<0.001
	Pulmonary	85.9%	0.534
	Solid organ	90.0%	0.124
	Pelvis	88.4%	0.210

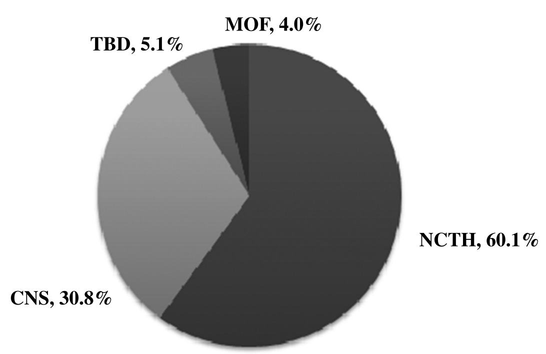
A



Abbreviations: ED/OR - Emergency Department / Operating Room, ICU - Intensive Care Unit, Pre-MTF - Pre-Medical Treatment Facility

The location and cause of death, n = 253.

B



Abbreviations: CNS - Central Nervous System Disruption, TBD - Total Body Disruption, MOF - Multiple-Organ Failure, NCTH - Non-Compressible Torso Hemorrhage

Primary cause of death, n = 253.

Figure 1. *A*, The location and cause of death, n = 253. ED/OR, emergency department/operating room; ICU, intensive care unit. *B*, Primary cause of death, n = 253. CNS, central nervous system disruption; TBD, total body disruption; MOF, multiple-organ failure.

The CFR was independent of operational theater, with a rate of 89.7% for Iraq and 84.5% for Afghanistan ($p = 0.407$) (Table 2). When analyzing the temporal trend across the decade of study, the cohort was divided into three equal tertiles (n = 99) covering the following periods: August 2002 to May 2008, May 2008 to December 2011, and December 2011 to July 2012. The CFR demonstrated a decreasing trend of 90.9%, 83.3%, and 81.6% across the respective groups, but this did not achieve statistical significance ($p = 0.155$). When comparing the CFR of the major anatomic NCTH domains, vascular injury is significantly higher when compared with nonvascular injury ($p < 0.001$) but remains similar for the remaining domains ($p > 0.1$).

In terms of injury pattern using an AIS score of 3 or greater as a marker of severe injury, as previously alluded by the ISS and NISS scores, there is a globally higher injury burden in nonsurvivors (Table 3). The biggest contributors to mortality on univariate analysis are severe head (7.0% vs. 39.9%, $p<0.001$) and chest (46.5% vs. 80.6%, $p < 0.001$) injuries. This pattern is broadly similar when comparing patients who survived to MTF admission (WIA + DOW) versus those who were died pre-MTF (i.e., KIA).

When considering the four major NCTH anatomic domains, vascular injury was the most lethal (30.2 vs. 68.0%, $p < 0.001$) when comparing survivors with nonsurvivors. This is also apparent in the comparison between the MTF versus no-MTF admission, with the addition that a greater proportion of solid-organ injuries die previously in the field (28.4% vs. 39.6%, $p = 0.053$). When analyzing the NCTH subdomains in greater detail, major arterial and liver injury are identified in both groups as significant contributors to mortality.

To adjust for multiple interactions, injury parameters, which had a $p < 0.2$ on univariate testing of survivors versus nonsurvivors, were entered into a logistic regression. The

TABLE 3. Injury Pattern, Survivors Versus Nonsurvivors

	Survivor	Nonsurvivor	p	MTF	No MTF	p
n	43	253		74	222	
AIS score ≥ 3						
Head	3 (7.0%)	101 (39.9%)	<0.001	13 (17.6%)	91 (41.0%)	<0.001
Face	0 (0)	19 (7.5%)	0.087	1 (1.4%)	18 (8.1%)	0.040
Neck	1 (2.3%)	42 (16.6%)	0.010	2 (2.7%)	41 (18.5%)	<0.001
Chest	20 (46.5%)	204 (80.6%)	<0.001	39 (52.7%)	185 (83.3%)	<0.001
Abdomen	27 (62.8%)	181 (71.5%)	0.280	51 (68.9%)	157 (70.7%)	0.769
Upper extremity	3 (7.0%)	74 (29.2%)	0.001	10 (13.5%)	67 (30.2%)	0.005
Lower extremity	17 (39.5%)	151 (59.7%)	0.014	36 (48.6%)	132 (59.5%)	0.107
NCTH domains						
Vascular	13 (30.2%)	172 (68.0%)	<0.001	31 (41.9%)	154 (69.4%)	<0.001
Pulmonary	11 (25.6%)	67 (26.5%)	0.901	18 (24.3%)	60 (27.0%)	0.648
Solid organ	11 (25.6%)	98 (38.7%)	0.124	21 (28.4%)	88 (39.6%)	0.053
Pelvic	11 (25.6%)	84 (33.2%)	0.322	24 (32.4%)	71 (32.0%)	0.525
NCTH Subdomains						
Major arterial	5 (11.6%)	152 (60.1%)	<0.001	17 (23.0%)	140 (63.1%)	<0.001
Minor arterial	4 (9.3%)	7 (2.8%)	0.059	7 (9.5%)	4 (1.8%)	0.003
Major venous	6 (14.0%)	55 (21.7%)	0.243	11 (14.9%)	50 (22.5%)	0.158
Minor venous	1 (2.3%)	5 (2.0%)	0.881	2 (2.7%)	4 (1.8%)	0.634
Pulmonary hilar	1 (2.3%)	26 (10.3%)	0.071	4 (5.4%)	23 (10.4%)	0.249
Pulmonary parenchyma	10 (23.3%)	48 (19.0%)	0.513	14 (18.9%)	44 (19.8%)	0.507
Renal	6 (14.0%)	38 (15.0%)	0.856	10 (13.5%)	34 (15.3%)	0.706
Liver	4 (9.3%)	73 (28.9%)	0.008	12 (16.2%)	65 (29.3%)	0.032
Spleen	3 (7.0%)	42 (16.6%)	0.104	4 (5.4%)	41 (18.5%)	0.005
Pelvic	11 (11.6%)	84 (33.2%)	0.322	24 (32.4%)	71 (32.0%)	0.525

All values are n with percentage in parentheses.

following parameters were used to build the regression model: severe head, neck, major arterial, minor arterial, pulmonary hilar, liver spleen, and extremity injury (Table 4). Several independent predictors of mortality in NCTH were identified and presented using odds ratios (ORs) and 95% confidence intervals (CIs). Major arterial and pulmonary hilar injuries were the most lethal NCTH domains, with a lesser contribution from liver trauma. Severe head, neck, and extremity injuries were major nontorso domains of injury.

DISCUSSION

This study is the first to comprehensively examine a population of wartime injured (including pre-MTF fatalities) using a contemporary definition of NCTH. The current study has demonstrated that 9 of 10 deaths in patients with NCTH occur in the pre-MTF phase of care, although the in-hospital mortality is also substantial. Furthermore, while NCTH directly contributes the bulk of deaths, there are other primary foci, the largest of which is concomitant CNS injury. The independent predictors of mortality from torso injury were major arterial, pulmonary hilar, and liver injury.

The current study confirms and extends the findings from a number of studies analyzing data from the wars in Iraq and Afghanistan. Holcomb et al. first coined the specific term *noncompressible truncal hemorrhage* in a cause-of-death analysis of 82 US military personnel killed between 2001 and 2004.[1] The cohort was reviewed by an expert panel, and patients were judged as having a potentially survivable or nonsurvivable injury. Of the potentially survivable deaths, 67% were caused by hemorrhage originating from the torso, only amenable to surgical control in the operating room. This landmark study provided a fresh perspective on classifying the cause of death from hemorrhage, which was largely based on the method of pre-MTF control. As experience from the war evolved, deaths from "tourniquetable" hemorrhage have decreased owing to improved pre-MTF hemostasis, specifically the deployment of hemostatic gauze and tourniquets.[5–7]

This approach to classifying hemorrhage was expanded upon in a study by Kelly et al.,[3] who compared the cause of death in US military personnel killed during two periods. The rates of truncal hemorrhage did not differ across the periods and

TABLE 4. Logistic Regression

Injury Region	OR	95% Confidence Interval	p
Head	6.46	1.78–23.42	0.005
Neck	9.00	0.98–82.35	0.052
Major arterial	16.44	5.50–49.11	<0.001
Minor arterial	0.430	0.081–2.30	0.324
Pulmonary hilar	9.61	1.06–87.00	0.044
Liver	6.00	1.71–21.04	0.005
Spleen	3.78	0.73–19.58	0.114
Extremity	4.22	1.72–10.34	0.002

Hosmer-Lemeshow statistic, 3.448; $p = 0.841$; $df = 7$; area under the curve, 0.892.

accounted for the majority cause (50%) of potentially survivable deaths. This has been further confirmed most recently by Eastridge and Mabry,[4] who examined the cause of death in US forces during 10 years of war. In total, there were 4,596 fatalities, with 87.3% occurring in the pre-MTF phase of care. There were 976 potentially survivable deaths, of which 67.3% were a consequence of truncal hemorrhage.

The cause of in-hospital combat-related death has also been examined within a clinical context, looking for opportunities for improvement. Martin et al.[16] examined 151 deaths admitted to an MTF where hemorrhage was the leading cause of nonexpectant death. There were 76 nonexpectant deaths, with at least one opportunity for improvement identified in 59 patients (78%). The largest region noted for improvement was in prehospital transport time and prehospital hemorrhage control. These findings add clinical context to the results from the current study, where the prehospital environment was the most common location of death.

Following these consistent findings, military surgeons from the United Kingdom and United States set out to formalize a definition of NCTH in terms of anatomic and physiologic parameters to be able to characterize this highly lethal, yet potentially survivable, injury complex. Morrison and Rasmussen[8] proposed the definition used in the current study, which was designed to be inclusive of all major foci of torso hemorrhage yet exclusive to patients presenting with shock or the need for immediate hemorrhage control. This definition was designed to be practical and to enable the comparison of populations or interventions used in the management of NCTH.

This definition has been applied by Stannard et al.[9] to US military personnel admitted to MTFs during an 8-year period. They identified an incidence of 12.7% of patients sustaining the anatomic injury pattern, with 17.1% of those patients demonstrating evidence of shock or the need for urgent hemorrhage control. Following adjustment using multivariate analysis, the most mortal injury complexes were major arterial injury (OR, 3.38; 95% CI, 1.17–9.74) and pulmonary injury (OR, 2.23; 95% CI, 1.23–4.98).

The current study extends these findings to include a military population who died in the pre-MTF phase of care. Almost 9 of 10 deaths occur before MTF admission, and again, major arterial injury and pulmonary hilar injury were identified as independent predictors of mortality, along with traumatic liver injury. It is useful to know that the NCTH injury patterns are consistent across populations that die before or after MTF admission because this has implications for future hemorrhage control and resuscitation strategies. Importantly, any novel device or treatment can be tested and refined in an MTF, before projecting forward, with the knowledge that although overall injury severity may increase, the major injury patterns are similar.

A further important finding from the current study is from the cause-of-death analysis. While all patients had sustained NCTH, death from uncontrolled hemorrhage only accounted for 60.1% of the primary cause of death. In almost a third of cases, CNS injury was graded as more severe than the hemorrhagic component, further supported by the regression finding that severe head injury was a strong independent predictor of mortality. While many of these patients likely sustained an unsurvivable CNS injury, this highlights the multisystem nature of modern combat injury and the need for a pre-MTF hemorrhage control strategy that incorporates neuroprotection. The current paradigm of hypotensive resuscitation in hemorrhage may compound secondary brain injury in patients with concomitant neurotrauma.

The current study has a number of important limitations to note. Despite the largest burden of mortality occurring in the pre-MTF phase of care, little is known regarding the physiology or care rendered during this crucial time. Furthermore, despite a population of almost 300 patients, owing to the volume of polytrauma, it is difficult to analyze subgroups in isolation. Regression was used to overcome the issue of multiple injuries; however, it is conceivable that some lesser injuries may be overshadowed by the dominant injury patterns.

CONCLUSION

This study demonstrates that the majority of patients sustaining NCTH die in the pre-MTF phase of care. Major arterial, pulmonary, and liver trauma are independent predictors of mortality. Injury pattern does not change significantly between patients surviving to MTF admission compared with patients dying before MTF admission, although overall injury burden does increase. The major cause of death is uncontrolled hemorrhage, although CNS disruption is an important contributor. Future hemorrhage control and resuscitation strategies must be forward deployed and incorporate a neuroprotective component to reduce the mortality from NCTH.

AUTHORSHIP

J.J.M. contributed to the study concept, data acquisition, analysis, interpretation, and writing. A.S. contributed to the study concept, data interpretation, and writing. T.E.R. contributed to the study concept, data interpretation, and writing. J.O.J. contributed to the data interpretation and writing. N.R.M.T. contributed to the study concept, data interpretation, and writing. M.J.M. contributed to the study concept, data acquisition, data interpretation, writing, and leadership.

ACKNOWLEDGMENT

We are grateful to the UK JTTR (Royal Centre for Defence Medicine, Birmingham, United Kingdom) for providing the data used in this study. We are also thankful for the statistical advice from Dr. Amy Apodaca-Morrison (US Army Institute of Surgical Research).

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

1. Holcomb JB, McMullin NR, Pearse L, Caruso J, Wade CE, Oetjen-Gerdes L, et al. Causes of death in U.S. Special Operations Forces in the global war on terrorism: 2001–2004. *Ann Surg*. 2007;245:986–991.
2. Eastridge BJ, Hardin M, Cantrell J, Oetjen-Gerdes L, Zubko T, Mallak C, et al. Died of wounds on the battlefield: causation and implications for improving combat casualty care. *J Trauma*. 2011;71:S4–S8.
3. Kelly JF, Ritenour AE, Mclaughlin DF, Bagg KA, Apodaca AN, Mallak CT, et al. Injury severity and causes of death from Operation Iraqi Freedom and Operation Enduring Freedom: 2003–2004 versus 2006. *J Trauma*. 2008;64:11–15.
4. Eastridge B, Mabry R. Death on the battlefield (2001–2011): implications for the future of combat casualty care. *J Trauma Acute Care Surg*. 2012; 73:S431–S437.

5. Kragh JF, Littrel ML, Jones JA, Walters TJ, Baer DG, Wade CE, et al. Battle casualty survival with emergency tourniquet use to stop limb bleeding. *J Emerg Med*. 2011;41:590–597.
6. Kragh JF, Walters TJ, Baer DG, Fox CJ, Wade CE, Salinas J, et al. Practical use of emergency tourniquets to stop bleeding in major limb trauma. *J Trauma*. 2008;64:S38–S49.
7. Kragh JF, Walters TJ, Baer DG, Fox CJ, Wade CE, Salinas J, et al. Survival with emergency tourniquet use to stop bleeding in major limb trauma. *Ann Surg*. 2009;249:1–7.
8. Morrison JJ, Rasmussen TE. Noncompressible torso hemorrhage. *Surg Clin North Am*. 2012;92:843–858.
9. Stannard A, Morrison J, Scott D, Ivatury R, Ross J, Rasmussen T. The epidemiology of noncompressible torso hemorrhage in the wars in Iraq and Afghanistan. *J Trauma Acute Care Surg*. 2013;74:830–834.
10. Patel S, Rasmussen TE, Gifford SM, Apodaca AN, Eastridge BJ, Blackbourne LH. Interpreting comparative died of wounds rates as a quality benchmark of combat casualty care. *J Trauma Acute Care Surg*. 2012;73:S60–S63.
11. Smith J, Hodgetts T, Mahoney P. Trauma governance in the UK defence medical services. *J R Army Med Corps*. 2007;153:239–242.
12. Holcomb JB, Stansbury LG, Champion HR, Wade C, Bellamy RF. Understanding combat casualty care statistics. *J Trauma*. 2006;60:397–401.
13. Barancik J, Chatterjee B. Methodological considerations in the use of the Abbreviated Injury Scale in trauma epidemiology. *J Trauma*. 1981;21:627–631.
14. Baker SP, Neill BO, Se B, Haddon W, Long WB. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14:187–196.
15. Osler T, Baker SP, Long W. A modification of the injury severity score that both improves accuracy and simplifies scoring. *J Trauma*. 1997;43:922–925.
16. Martin M, Oh J, Currier H, Tai N, Beekley A, Eckert M, Holcomb J. An analysis of in-hospital deaths at a modern combat support hospital. *J Trauma*. 2009;66:S51–S60.